On Anchoring Sentences in Actions

Semantics and Philosophy in Europe 4

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Outline

Linguistics vs. Action Theory

- Logical analysis of *sentences* that describe action vs. Logical analysis of *action* described by sentences
- Different focus and vocabulary of linguistic and action-theoretic approaches to the meaning of action sentences.
- This talk: how can we combine linguistic and action-theoretic approaches to action sentences?

Sentences that describe action

- [Davidson, 1967]: The logical analysis of action *sentences*
- Introduction of a new ontological sort of entities: “events” to predicate logic
  - Brutus stabbed Caesar with a knife ⇒ Brutus stabbed Caesar.
- Events link verbs with their arguments and adjuncts on a *syntactic* level.

Davidsonian Event Semantics

- *Semantic* interpretation of Davidsonian Events?
- Interpret reference markers for events on par with reference markers for “standard” individuals
- Model contains a set of events with the help of which formulas containing event markers are evaluated
- E.g.: given a set of events E structured by $<$, a universe of individuals U and an interpretation function I,
  - $[\![R(e, x_1, \ldots, x_n)]\!]^{M}, g = 1$ iff $\langle g(e), g(x_1), \ldots, g(x_n)\rangle \in I(R)$
- where g is an assignment that maps e onto an element of E and $x_1, \ldots, x_n$ onto elements of U.
- Thus: events described by occurrences of e.g. “build a house” are events that stand in some ’build’-*relation* to the one who is doing the building (or the ones who are doing the building) and the thing that is built.

Fine grained event semantics?

- Davidsonian event semantics analyzes action sentences in terms of *relations* between individuals and events, not in terms of the *action* that is described.
- Causes problems when it comes to the subatomar structure of events (Moens and Steedman [1988])

Example: Tense and Aspect

- How to capture the different types of event complexes that can be described with action verbs? (“Aktionsart”, [Vendler, 1957])
  - E.g. ’run’ vs. ’build a house’ vs. ’reach the top’
- How to capture the interaction between aspect, tense and events?
  - E.g. John was building a house $\not\Rightarrow$ John built a house
    But: John was running $\Rightarrow$ John ran.
- Complex subatomar structure of events that can not be captured with the specification of pre-/postconditions but is related to the actions that are described.

Action described by sentences

- Logical analysis of *action* described by sentences
- Add modal operators to the language of propositional logic:
  - STIT [Belnap et al., 2001] e.g.: “x sees to it that p”
  - BDI [Rao and Georgeff, 1991] e.g.: “x intends that p”
- Semantic interpretation of these operators in a model theory with branching time
- Connection between action-theoretic approaches and events?

Action-theoretic approach to events

- Experimental Evidence: Segmentation of events along the assumption of underlying causal/plan-goal/intentional structures (see e.g. the collection of papers in [Shipley and Zacks, 2008])
- Conceptual: Explanation of temporal variation with causal/ behavioral/intentional explanation patterns
- Linguistics: Close connection between planning and events [van Lambalgen and Hamm, 2004]
- Idea: use action logic to formalize the segmentation, constitution and internal structure of events.
  - But: Connection between natural language semantics and action formulas?

Anchors in Discourse Representation Theory (DRT)

- Anchors were introduced to DRT [Kamp, 1984] as a means to represent puzzles of reference in propositional attitude ascriptions ([Kamp, 1984-85, Asher, 1986])
- An anchor is a two-place relation between a discourse reference marker (a “floater”) and a specification of its relation of acquaintance (a “source”): $\langle \mathit{floater}, \mathit{source} \rangle$

Linking Natural Language Semantics and Action Theory

- Here: specify anchor sources for temporal entities with the help of operators from action logic.
- Consider not only pre-/postconditions of events but also the (sequence of) action (+ additional information on these actions such as intentions) which connect these conditions.
- This talk: adopt ideas from the BDI-interpretation of CTL* proposed by [Singh, 1994]

Temporal anchors: Syntax and Semantics

Syntactic representation of temporal anchors:

e
$\langle e, x\text{OP}K\rangle$
$name(e)$
- where OP is one of the operators PATH,PLAN,INT and K a DRS.

Semantic interpretation of temporal anchors:

- OP specifies a (branching) temporal structure which is assigned to e by a function $SEM_name(e)$.

Branching-time Structures

A branching-time structure is a tuple $E = \{\mathbf{T}, \mathit{I}, \mathit{Actions}\}$, where

- $\mathbf{T} = \langle <, \mathbf{Times} \rangle$, where **T** is a labeled directed graph with node set **Times**, arc set *Actions* and node labels given by *I*. In addition, we require the graph of **T** to be a tree.
- *I* associates times $t \in \mathbf{Times}$ with interpretations, i.e. an information structure representing the state of affairs at *t*.

Branching-time Structures

- *Actions* is a function from pairs $\langle t, t' \rangle$ of adjacent members of **Times** to Agents.
- $\mathbf{S}(x)(t)$ is a function from Scenarios to agents at a time. A scenario is any maximal set of moments containing the given moment, and all moments in its future along some particular branch.
- $\mathbf{P}(x)(t)$ is a function from substructured of **T**. to agents at a time and assigns plans to agents.
- $\mathbf{Int}(x)(t)$ is a function from **T** to agents at a time and assigns intentions to agents.

Example: Simple Past

Example (“Peter built a house”)

$$\begin{array}{|l|}\hline e_0, x, n \\ \langle e_0, x\text{PATH} \begin{array}{|l|}\hline y \\ house(y) \\ \hline \end{array} \rangle \\ e_0 \prec n \\ build(e_0) \\ Peter(x) \\ \hline \end{array}$$

Temporal anchors: Model-Theoretic Semantics (1)

- Past tense: $e \prec n$
- $\langle e, x\mathrm{PATH}K \rangle \vDash_{M,S,t} name(e)$
  - iff $\exists [S; t, t_1] \in \mathbf{S}(x)(t)$ sth. $t_1 \prec n$ and $S \in SEM_{name}(e)$ and $\vDash_{M,t_1} K$

Example: Present Progressive

Example (“Peter is building a house”)

$$\begin{array}{|l|}\hline x, e_0, n \\ \langle e_0, x\text{INT} \begin{array}{|l|}\hline e_1 \\ \langle e_1, x\text{PLAN} \begin{array}{|l|}\hline y \\ house(y) \\ \hline \end{array} \rangle \\ e_1 \subseteq e_0 \\ e_0 <_{beg} e_1 \\ build(e_1) \\ \hline \end{array} \rangle \\ n \in e_0 \\ be(e_0) \\ Peter(x) \\ \hline \end{array}$$

Temporal anchors: Model-Theoretic Semantics (2)

- INT
  $\langle e, x\text{INT}K\rangle \vDash_{M,t} name(e)$
  - iff $[K]_{M,t} \in \mathbf{INT}(x)(t)$;
- PLAN: $n \in e$
  $\langle e, x\text{PLAN}K\rangle \vDash_{M,S,P,t} name(e)$
  - iff $\exists[S; t_0, n] \in \mathbf{S}(x)(t)$ and $\exists[P; n, \{t_1, \ldots, t_n\}] \in \mathbf{P}(x)(t)$ sth. $(S \cup P) \in SEM_{name}(e)$ and $(\vDash_{M,t_1} K \wedge \ldots \wedge \vDash_{M,t_n} K)$

Example: Past Progressive

Example ("Peter was building a house")

$$\begin{array}{|l|}\hline x, e_0, n \\ \langle e_0, x\mathrm{INT} \begin{array}{|l|}\hline e_1 \\ \langle e_1, x\mathrm{PLAN} \begin{array}{|l|}\hline y \\ house(y) \\ \hline\end{array} \rangle \\ e_1 \subseteq e_0 \\ build(e_1) \\ \hline\end{array} \rangle \\ e_0 \prec n \\ be(e_0) \\ Peter(x) \\ \hline\end{array}$$

Temporal anchors: Model-Theoretic Semantics (3)

- INT
  $\langle e, x\text{INT}K \rangle \vDash_{M,t} name(e)$
  - iff $[K]_{M,t} \in \mathbf{INT}(x)(t)$;
- PLAN: $e \prec n$
  $\langle e, x\text{PLAN}K \rangle \vDash_{M,S,t} name(e)$
  - iff $\exists [S; t, t_1] \in \mathbf{S}(x)(t)$ sth. $t_1 \prec n$ and $S \in SEM_{name}(e)$

Summary

- Temporal anchors provide an action-based verb semantics
- Main advantage from the linguistic point of view: complex structure of events takes into account not only preparatory and consequent state but also the actions that connect these states.
- Main advantage from action-theoretic point of view: possibility to take into account complex (temporal) relations between intentions, actions and goals.

Outlook

- Current Research Project: Rule-based account for the parallel construction of semantic representations and branching temporal structures in the framework of lexical DRT.
- Requires a notion of model dynamics, i.e. of the dynamic *interpretation* of semantic representations.
- Idea: The construction of temporal anchors manipulates the model theory via updates of the function that assigns temporal structures to events. ([Baltag et al., 1998], [Pross, 2010])

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Aktionsart

- Activity: Focus on the sequence of action (walk)
- Accomplishment: Focus on the sequence of the action and the goal (build a house)
- Achievement: Focus on the preconditions, sequence of action and the goal (reach the top).

Syntax of EPSs

EPS vocabulary

- A set T_R of EPS reference markers for things: $\{a_1, \ldots, a_n, \ldots\}$
- For each $n > 0$ a set Rel^n of n-place predicate constants for names $\{C_1, \ldots, C_m, \ldots\}$
- A set **Times** of EPS times $\{t_0, \ldots, t_n, \ldots\}$[1]

Syntax of EPSs and EPS conditions

1. If $U \subseteq T_R \bigcup$ **Times**, Con a (possibly empty) set of EPS conditions then $\langle U, Con \rangle$ is an EPS
2. If $R_1 \in Rel^n$ and $a_1, \ldots, a_n, \ldots \in T_R$ then $R_1(a_1, \ldots a_n)$ is an EPS-condition
3. A time-indexed EPS is a tuple $\langle t, \langle U, Con \rangle \rangle$.

[1] The numerical subscripts are used only to clarify the design of the EPS structure.

Anchors in DRT

- "External" anchors: Definite NPs directly contribute their reference $\langle x, a \rangle$
- "Internal" anchors: Relation of acquaintance in which reference markers stand to their reference $\langle x, DRS \rangle$)